Evaluation of OMI Cloud Pressure from Rotational Raman Scattering Using Aircraft and Satellite Data

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Outline

- Background and summary of validation campaign results
- Radiative transfer simulations with Rotational Raman Scattering (RRS) for a model of Plane-Parallel Cloud (PPC)
- Comparisons of OMCLDRR cloud pressures with OMTO3 and MODIS climatology
- Effect of cloud pressures on OMTO3 total ozone retrievals
- Comparisons of OMI cloud pressures with Cloud Physics Lidar (CPL) cloud-top pressures and Cloud Radar System (CRS)
- Conclusions

Background

- Estimates of cloud pressure are needed to accurately derive trace gas information from UV/VIS spectrometers and are important in their own right for climate
- There are two methods to estimate cloud pressure with OMI:

1) Rotational-Raman scattering (RRS) in the UV 2) O_2-O_2 absorption at 477 nm
  - Both differ fundamentally with IR emission (e.g. MODIS) in that cloud shield atmosphere below from Rayleigh/Raman scattering or O2-O2 absorption
  - Both methods are new; have not been used in an operational setting
  - Both methods were tested pre-launch with GOME (near nadir; morning orbit); RRS at 360 nm agreed well with O_2-A band from GOME, improved O_3
- Both methods use the Mixed Lambertian-Equavalent Reflectivity model
  - Cloud reflectivity adjusted empirically to account for light penetration in thin/broken clouds based on limited modeling
  - OMI trace-gas algorithms use this model
- V1 OMCLDRR algorithm uses large filling-in of Ca Fraunhofer lines between 392-398 nm
  - large signal mitigates striping errors
  - Soft-calibration based on Antarctica data (assume minimal cloud effect)

Summary of results from INTEX-B, AVE and MODIS comparisons (see Vasilkov poster for more details)

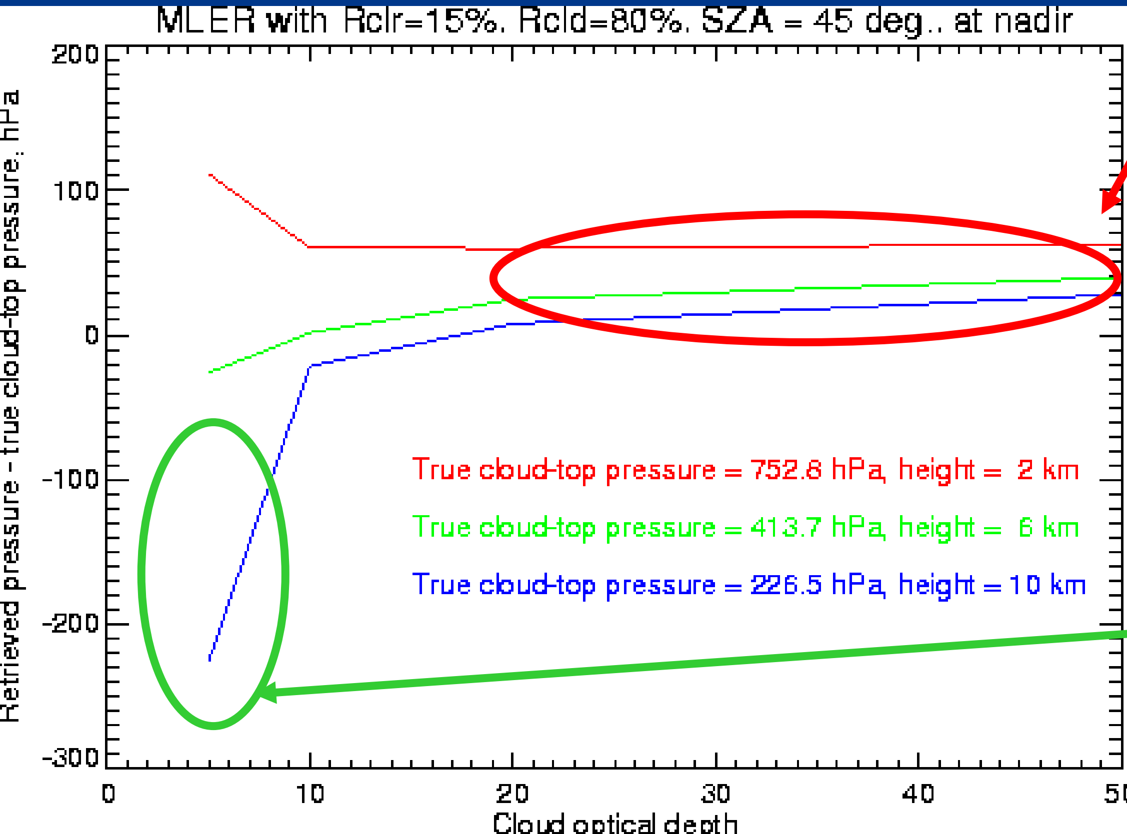
- There are significant differences between OMI cloud algorithms (analysis on-going)
- Cloud pressures too low in presence of absorbing aerosol; Aerosol index is not always a good indicator of aerosol in/above clouds.
- V1 Cloud pressures too low (sometimes negative) in thin/patchy clouds (problems with MLER model)
- Comparisons with MODIS show that differences in the presence of multiple cloud decks depend on the optical thickness of the upper cloud deck (as indicated by MODIS cirrus reflectance).
- Filling-in of solar lines due to Raman scattering is extremely sensitive to non-Lambertian behavior such as sea glint and non-Lambertian surfaces
  - Direct beam is not Rayleigh/Raman scattered; appears as a very high cloud
  - Effect on absorbers (O2-O2) is opposite – biases results toward surface pressure.

Plane parallel cloud radiative transfer simulation, retrieval of MLER cloud pressure:

Can we simulate what we see in the OMI data?

- LIDORT-RRS (Spurr) code calculates radiance and RRS filling-in
- Simulations of plane-parallel cloud (PPC) cloud-top heights of 2-10 km (1 km thick), cloud optical depths 5-50, and surface albedo 0.05, 392 nm (V1 wavelengths)
- Absorbing aerosol (τ=1.0 and ω_0=0.9) above/beneath cloud
- Multiple cloud decks (vary optical depth of both decks)
- Cloud pressure retrieved with MLER model

Errors in MLER Cloud Pressures



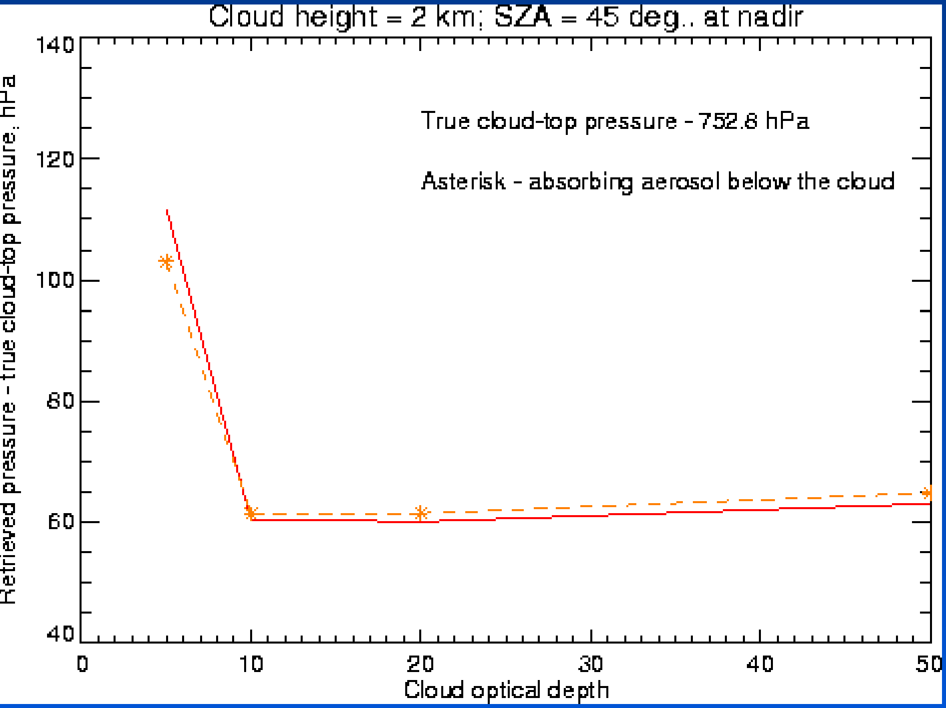
- **Deep convective clouds and optically thick fontal clouds:** MLER produces small errors, slightly overestimates cloud pressure

-Cirrus (high thin clouds): MLER cloud pressures are erroneously low. This effect is seen in OMCLDRR retrievals (e.g. some negative cloud pressures in V1).

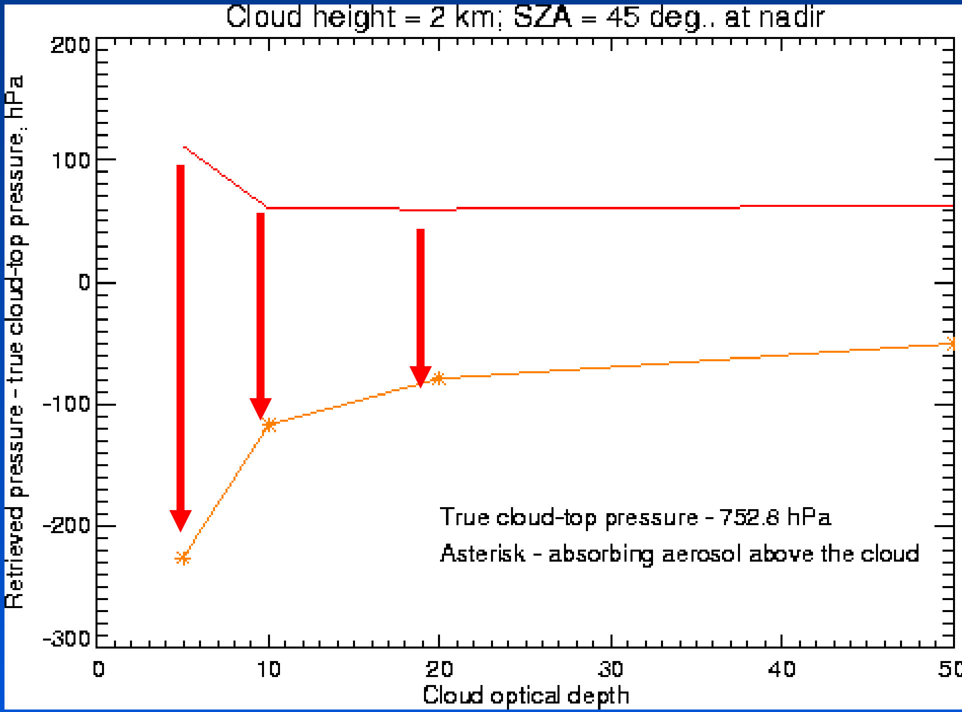
Reflec	0.30	0.47	0.65	0.83
Cl frac	0.20	0.45	0.74	1.0

Cloud pressure error from absorbing aerosol

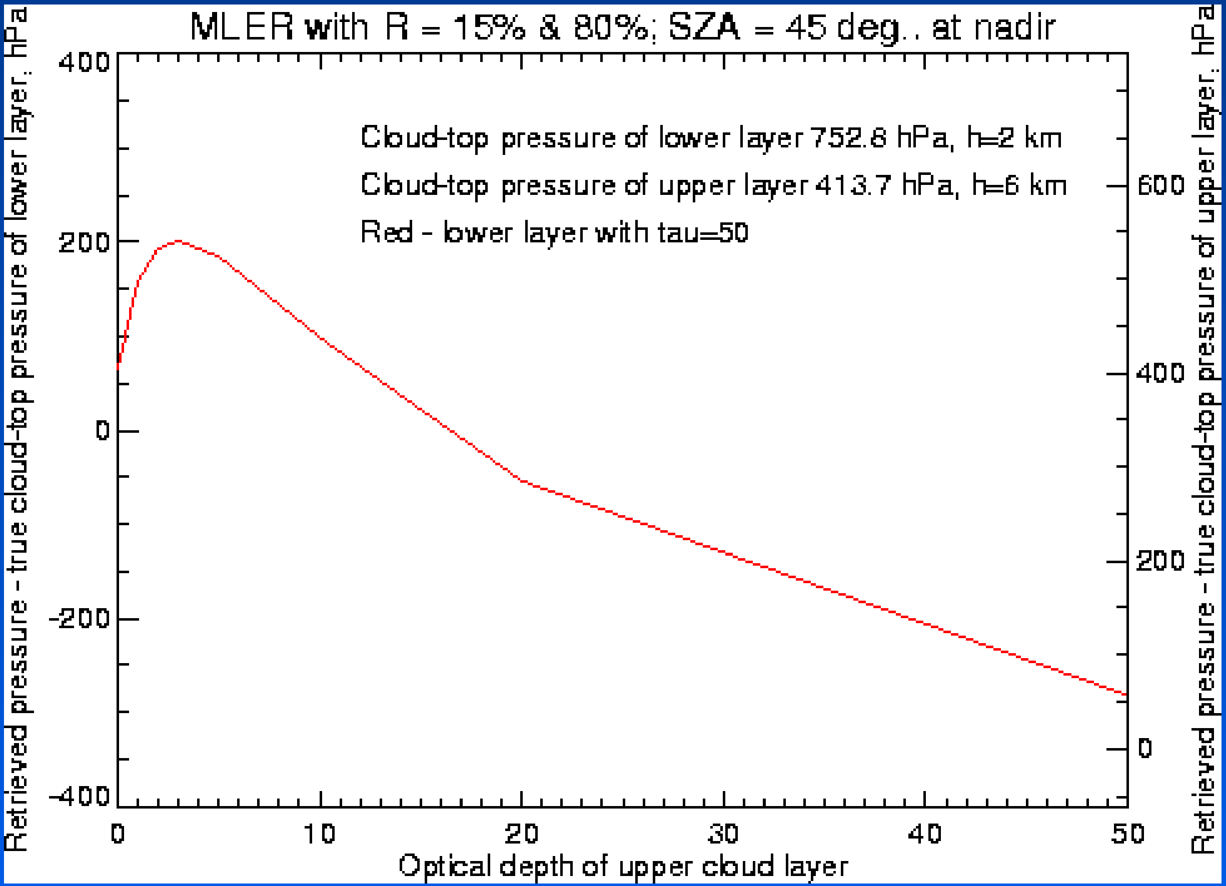
Below the cloud (negligible effect)



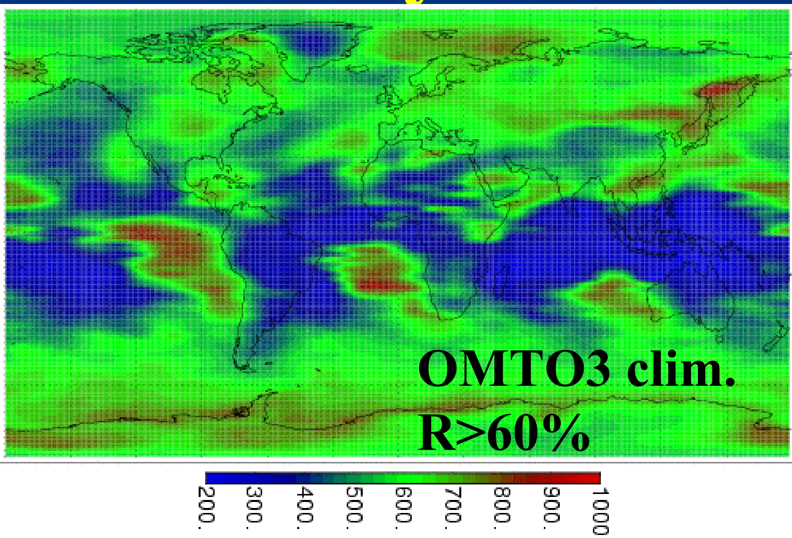
Above the cloud (erroneously low cloud pressure) – suggested in INTEX data



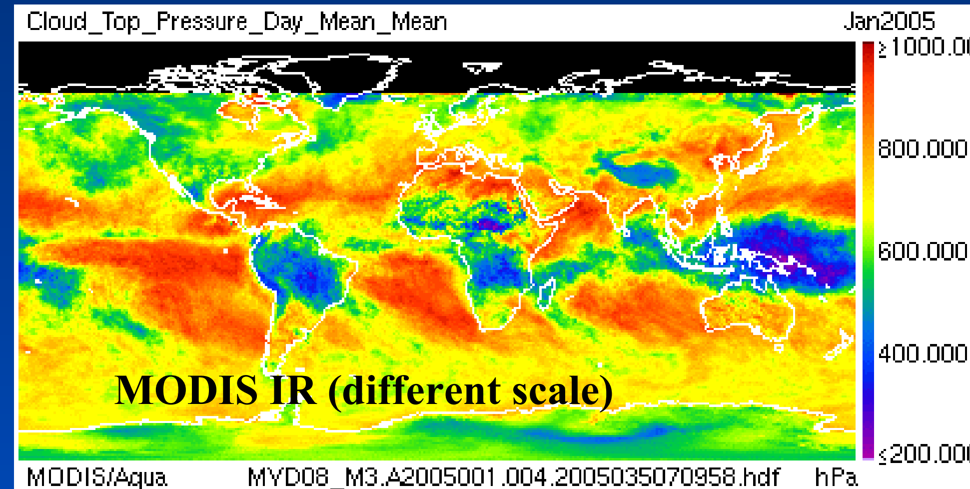
Simulation of 2 layer cloud



Monthly mean cloud pressures (Jan 2005)

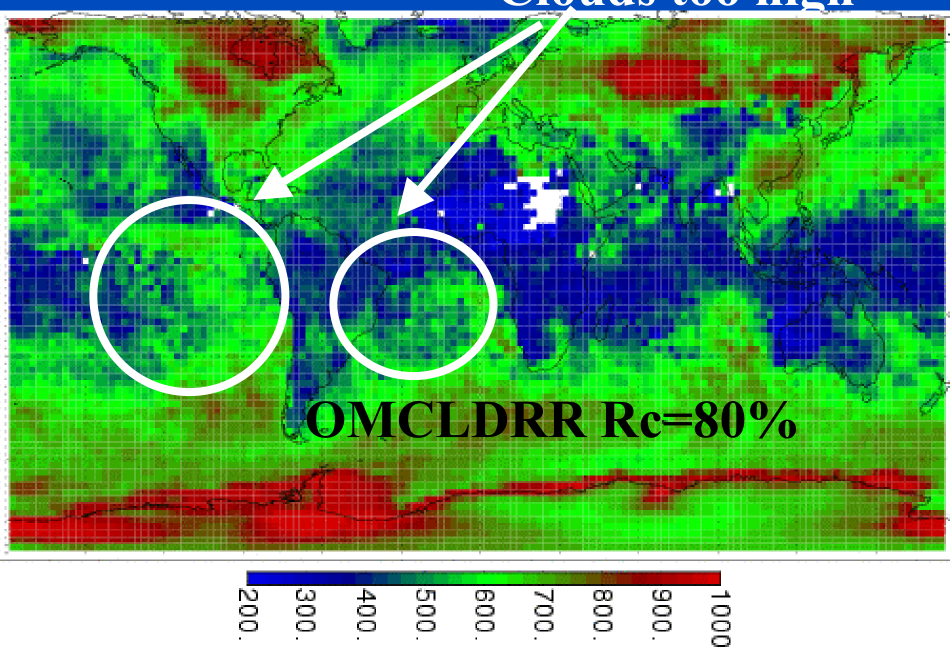


OMI v8 climatological cloud pressure (hPa) month 01

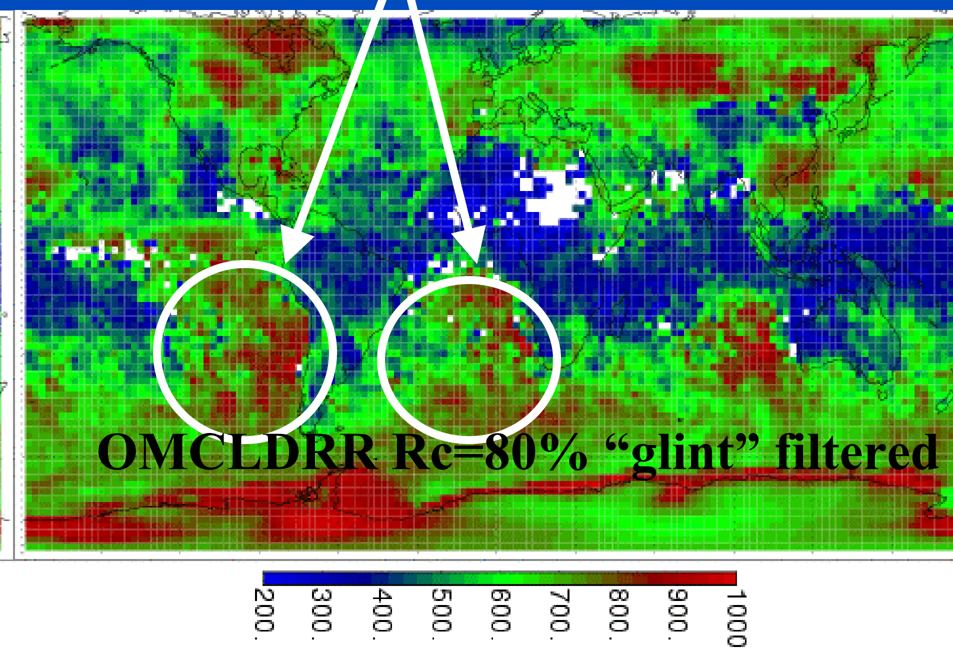


More low clouds center of swath removed

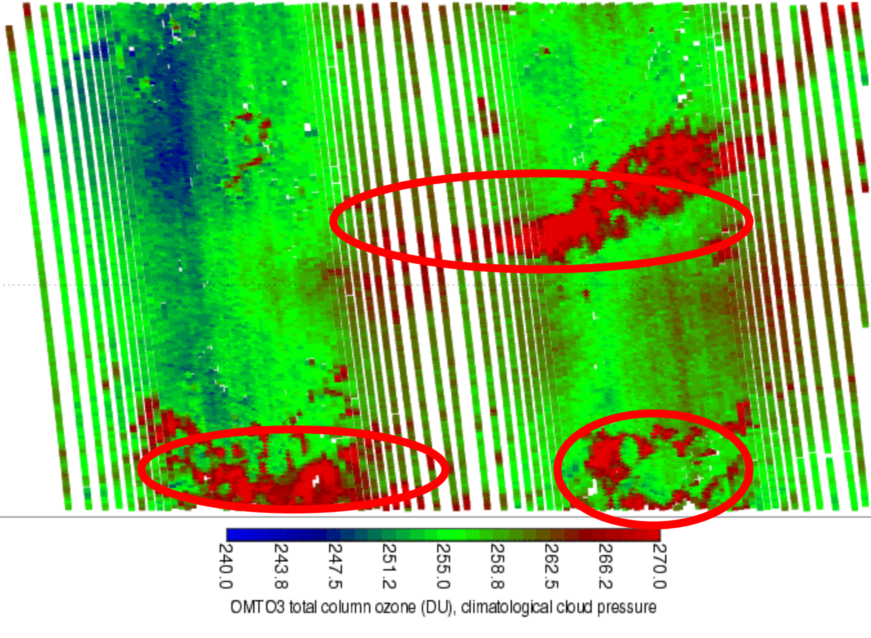
Clouds too high



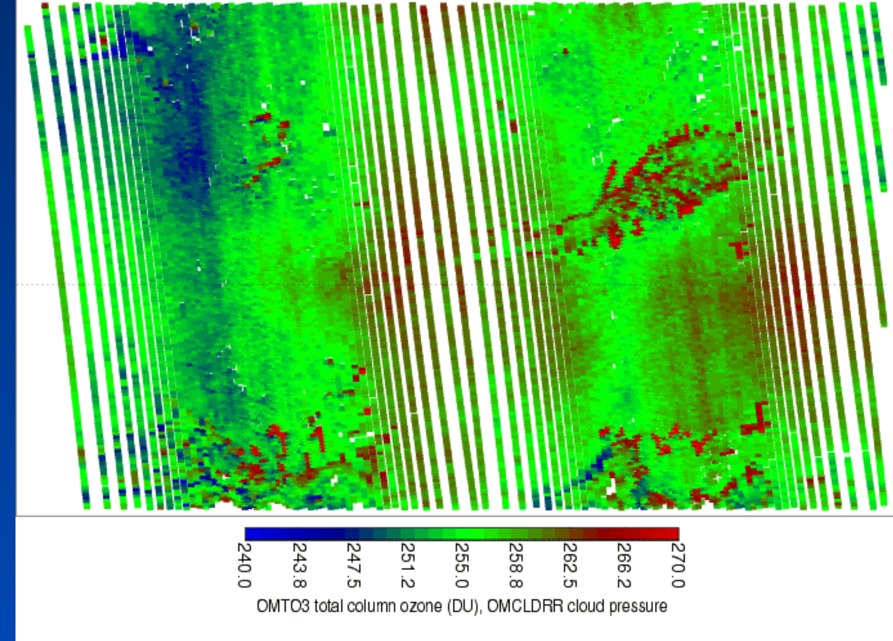
OMI mean LER (hPa) clim_omi_1580_40_new_100_M01.dat



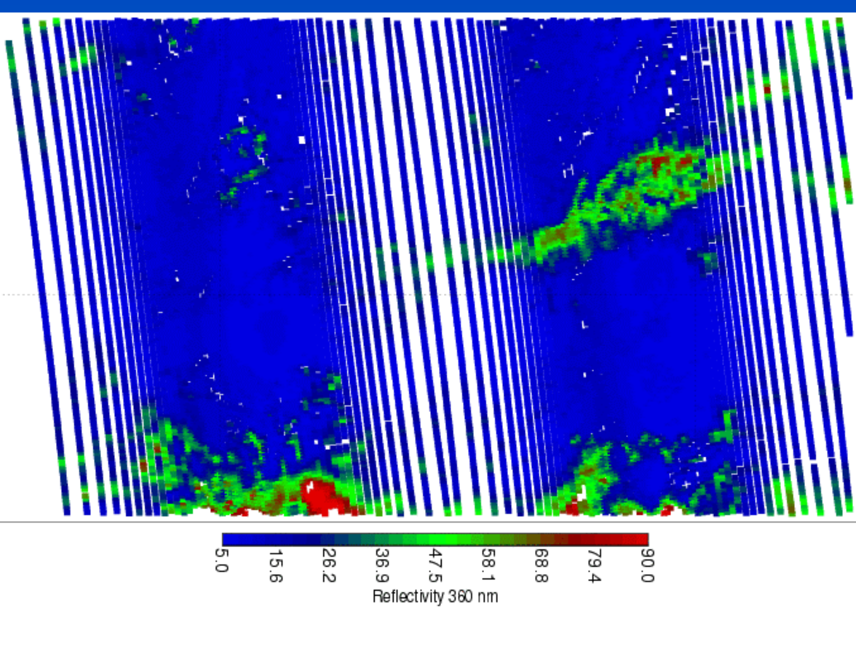
OMI mean LER (hPa) clim_omi_1580_40_edge3_100_M01.dat

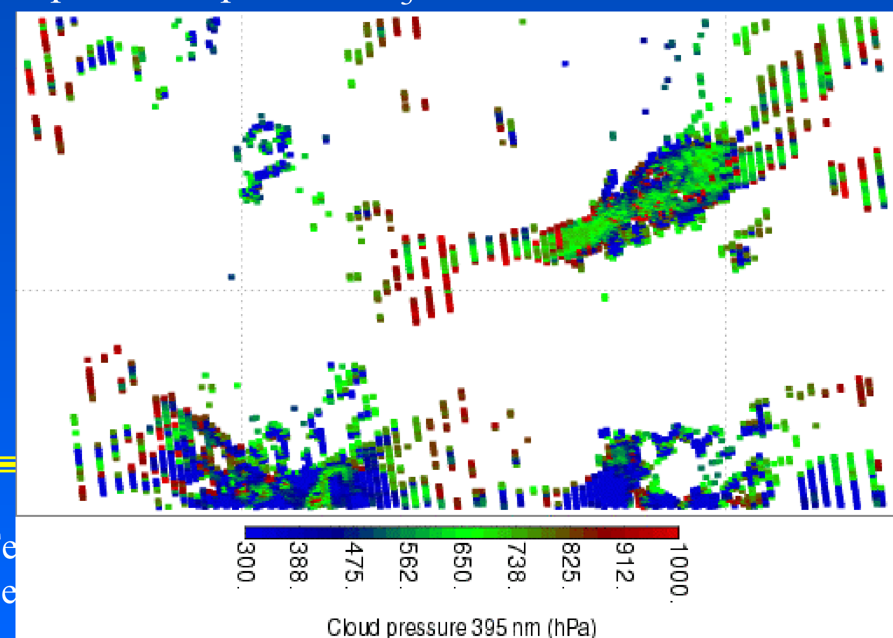


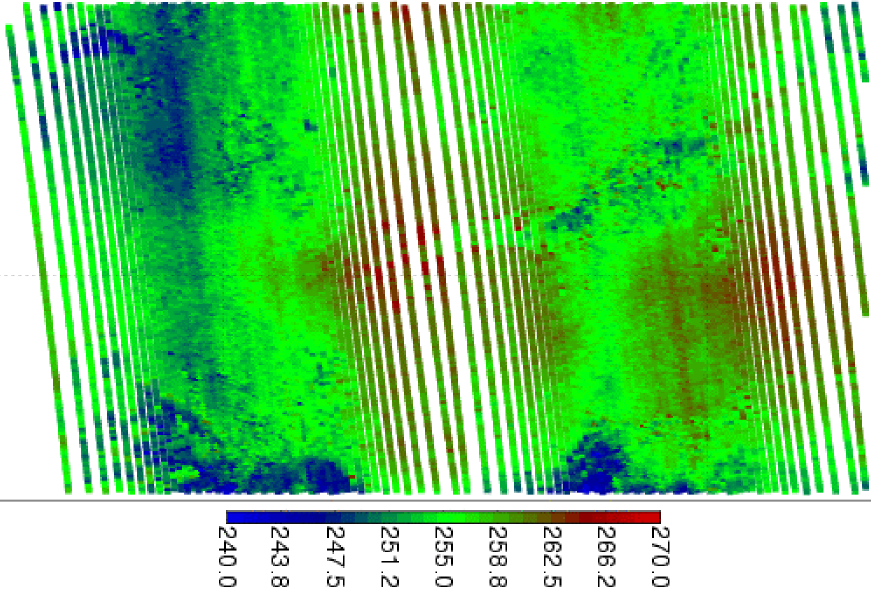
Obvious OMTO3 O_3 errors due to incorrect climatological cloud pressures



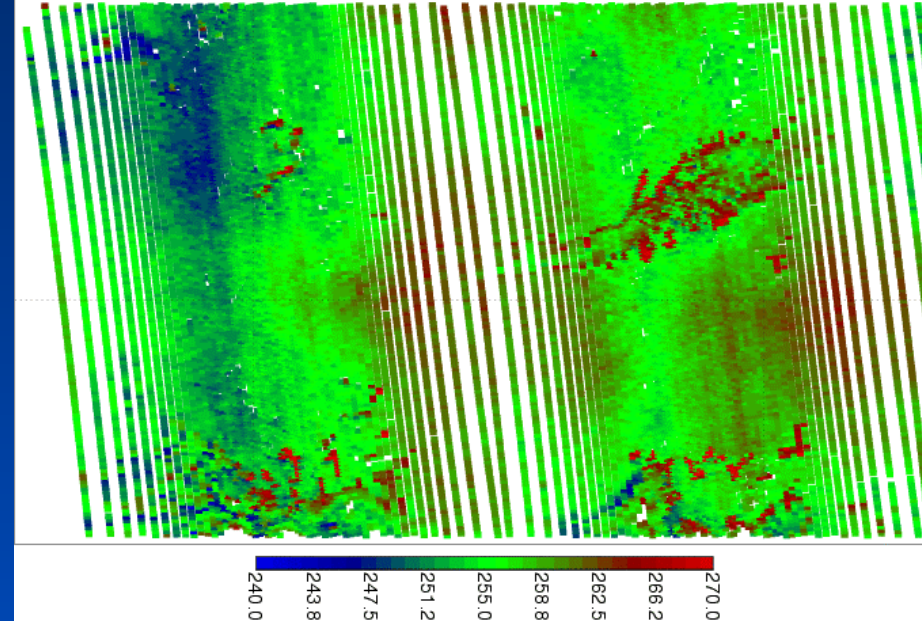
Some improvement using OMCLDRR cloud pressures, but at cloud band edges, too low pressures produce O_3 errors







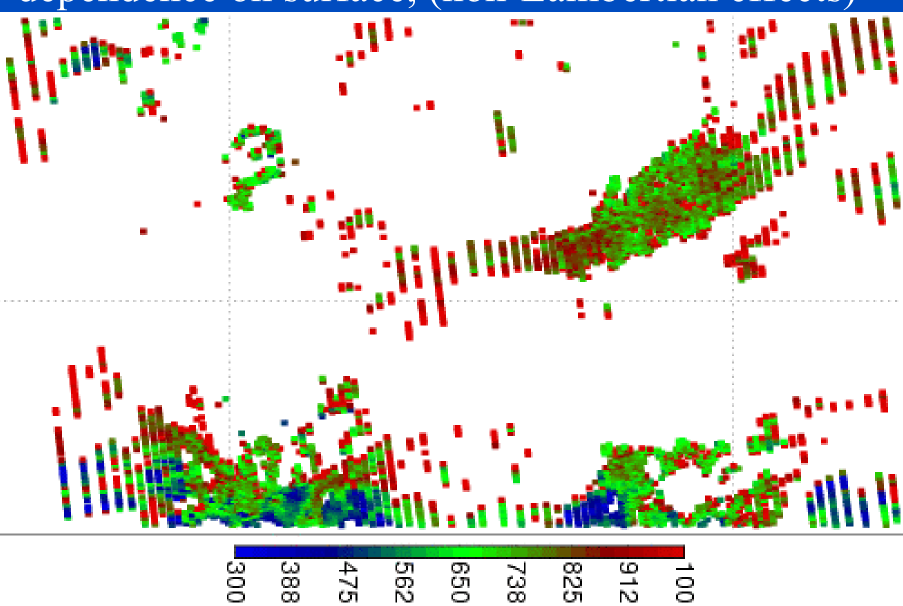
OMTO3 total O3 (DU) Cloud pressure 350 nm



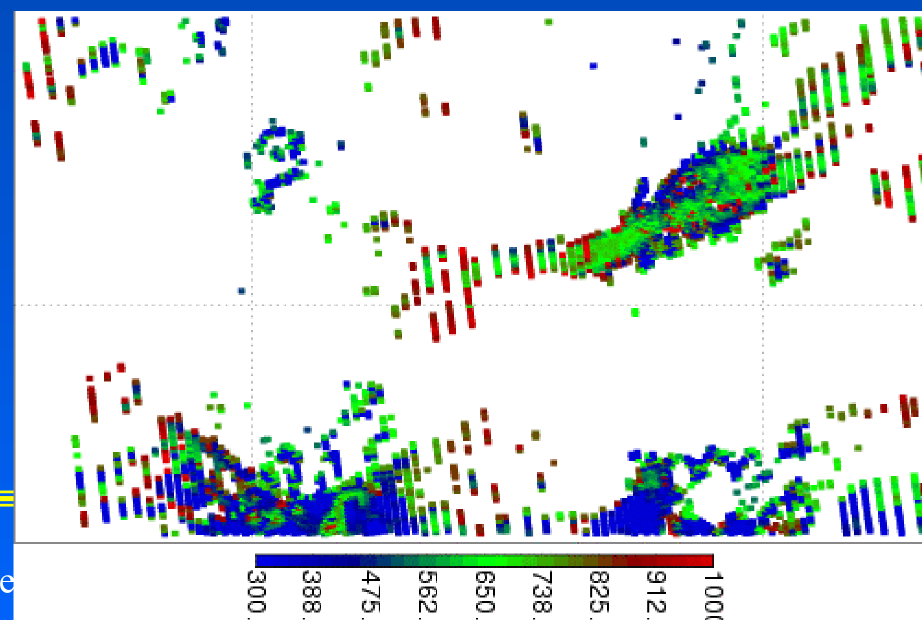
OMTO3 total column ozone (DU), OMCLDRR cloud pressure

Using shorter wavelengths for cloud retrieval improves pressures at cloud band edges; reduces dependence on surface, (non-Lambertian effects)

Same as in previous slide (V1 from 392-398 nm



Cloud pressure 350 nm (hPa)



Cloud pressure 395 nm (hPa)

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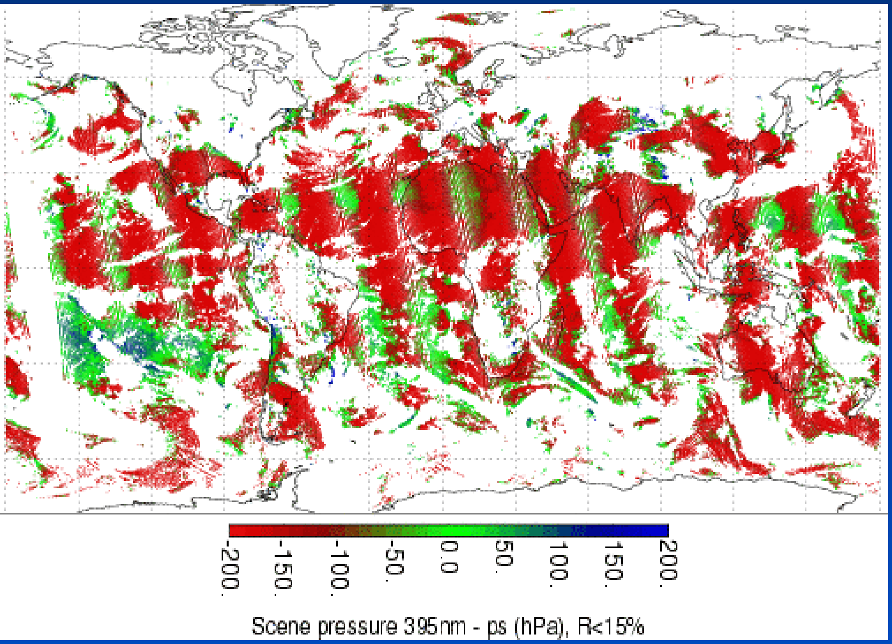
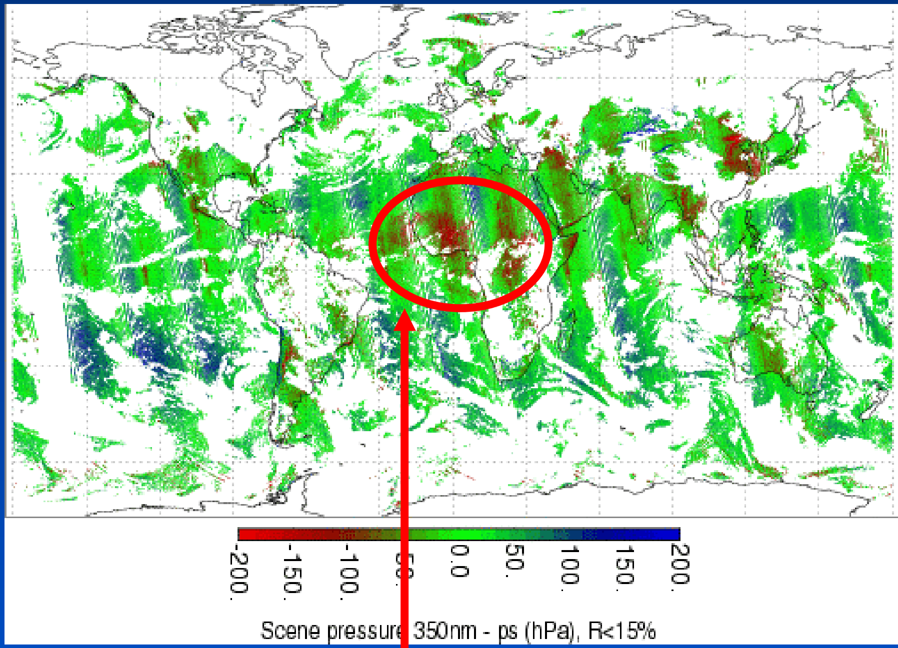
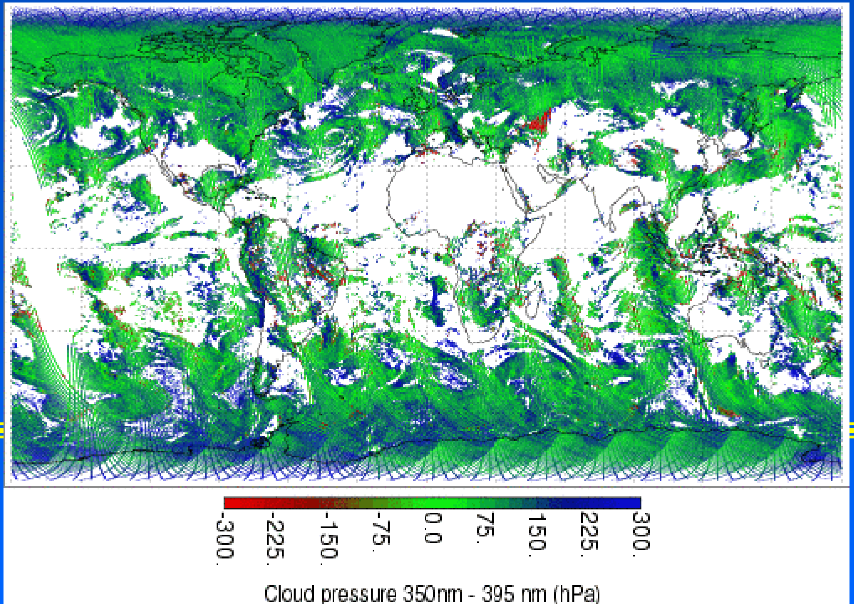
Clear scene diagnostic (Pcld-Psurf); 350-395 nm differences





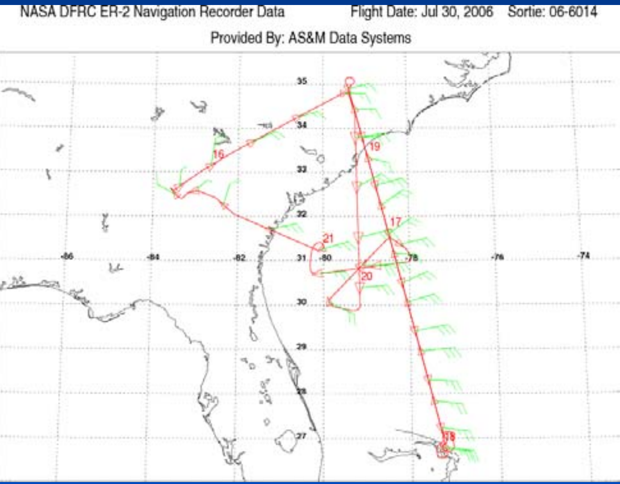
395 nm: Significant negative bias and swath dependence, produces too low pressures in thin/broken clouds

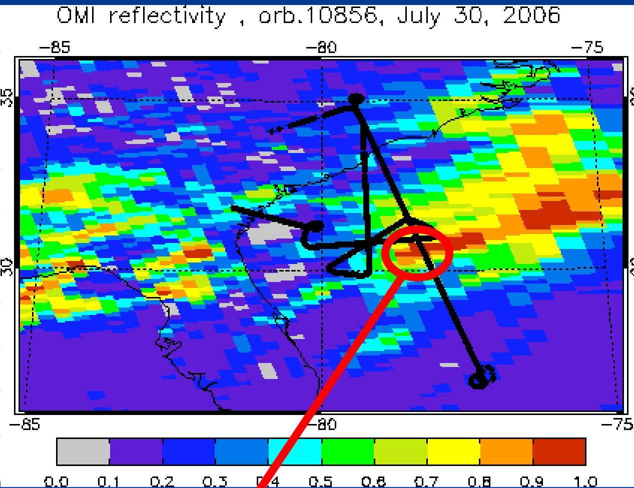
350 nm: Bias and swath dependence much reduced, aerosol effect now obvious

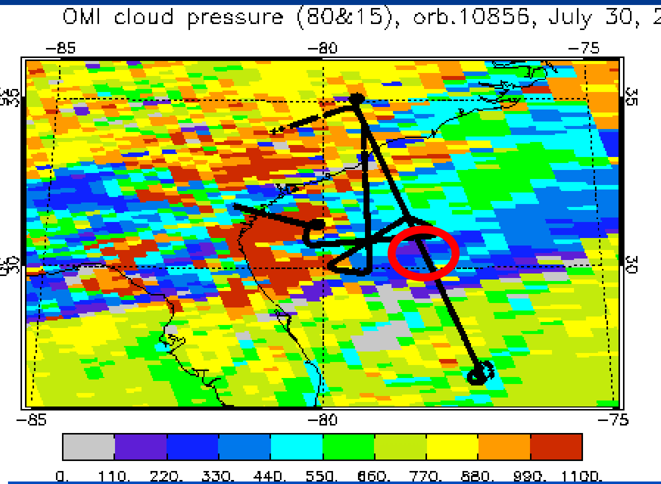


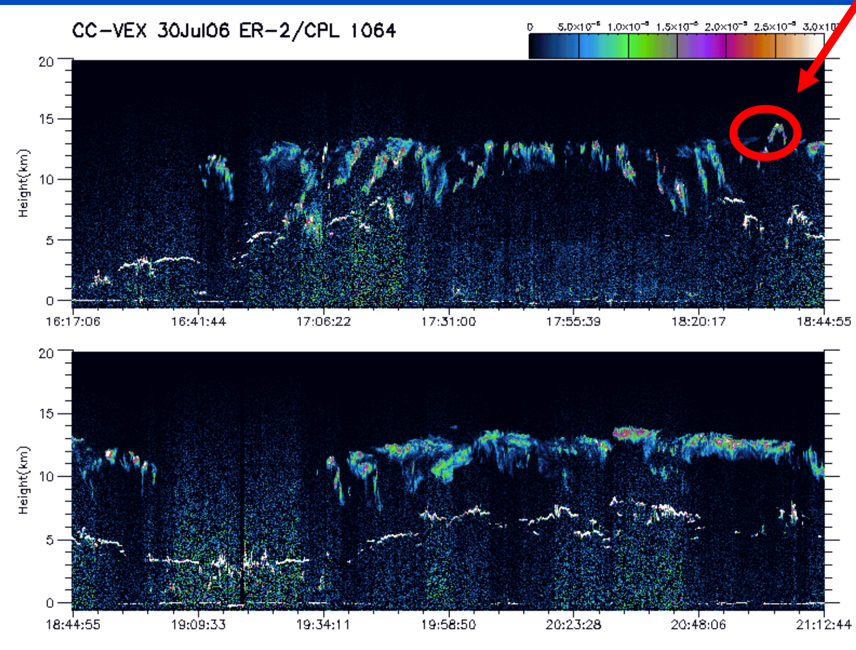
In cloudy regions, largest differences between 350 and 395 occur in thin/broken clouds, center of swath (fixes problems with V1)

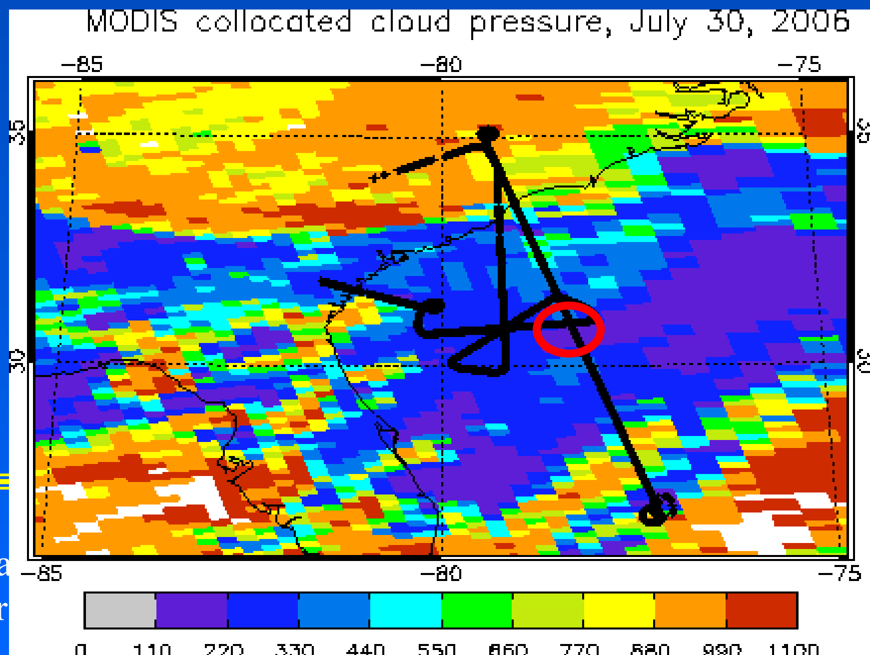
Comparisons with CPL and CRS (06' CALIPSO/CloudSat)











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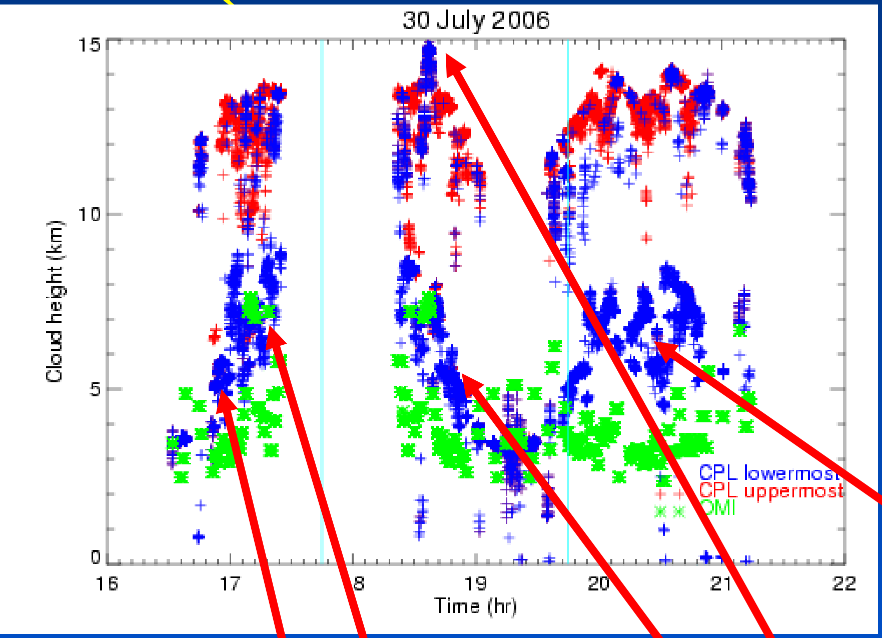
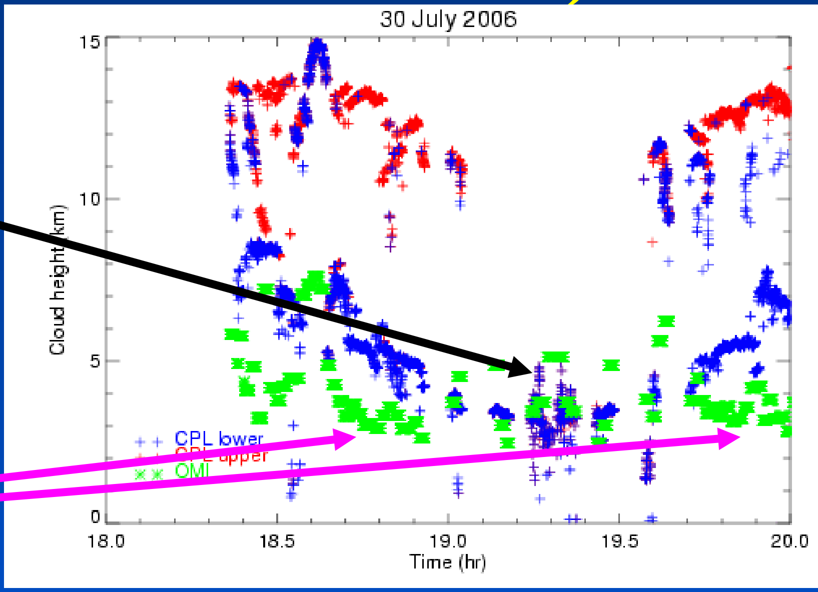
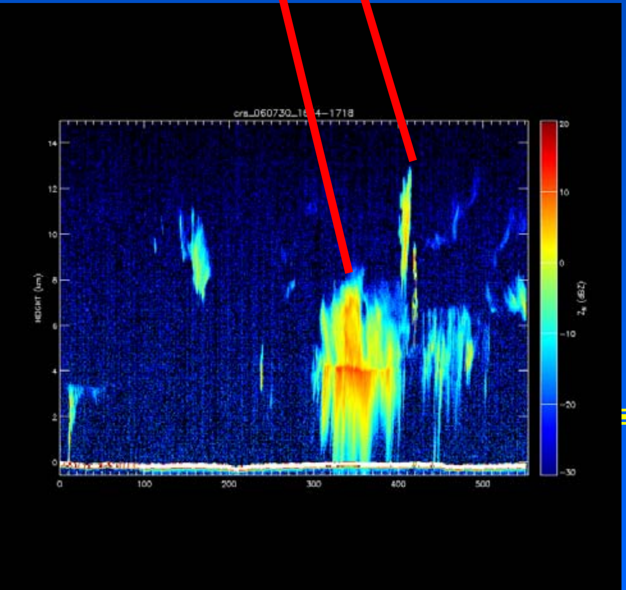
Comparisons with CPL & CRS (V2) (06' CALIPSO/CloudSat validation)

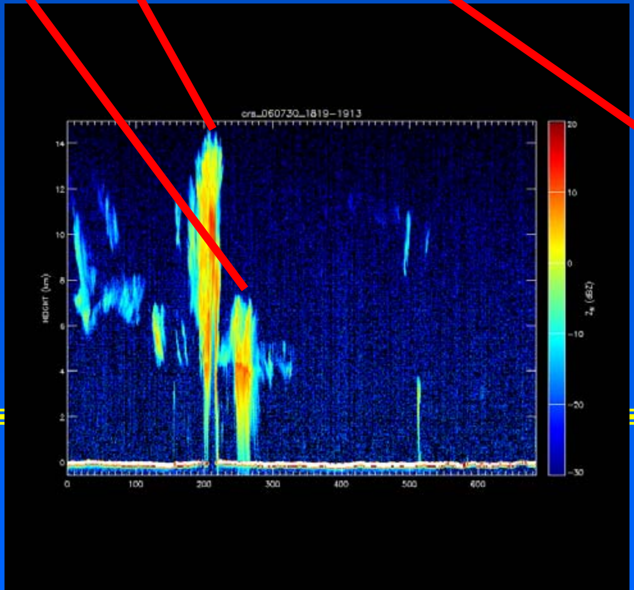


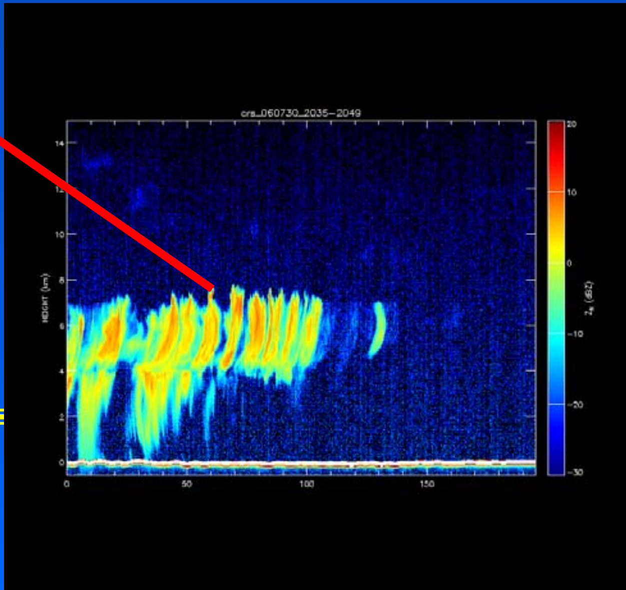
OMI cloud pressures closer to CPL lower cloud deck when upper deck absent;

OMI has higher pressure than CPL with upper deck









Summary and Future Work

- ✓ Non-Lambertian behavior produces erroneously low cloud pressures
  - ✓ Cloud shadowing
  - ✓ Sea glint
  - ✓ Thin cloud phase function
  - ✓ Non-Lambertian surface (low reflectivities; broken, thin clouds)
- ✓ Errors in chlorophyll climatology (produces errors in thin/broken clouds only)
- ✓ MLER in thin/broken clouds can produce too low cloud pressures
- Absorbing aerosol (above cloud) produces too low cloud pressures (suggests sensitivity to aerosol height as simulated)
- Multiple cloud decks produce difference wrt IR, pressures closer to lower cloud deck.
- ✓ Problems mitigated by using shorter wavelengths with more Rayleigh scattering, no ocean Raman scattering (V2 will be released soon!)
- Plan more validation with Cloudsat and Calipso